MICROCONTROLLER BASED LAPTOP COOLING SYSTEM

By

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CERTIFICATION OF APPROVAL

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Approved:

____

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May 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nurul Akmal Muhamad Shukri

ABSTRACT

The main objective of this project is to deliver an implementation of microcontroller based laptop cooling system. This project involves the development of a better cooling system for laptop which includes the temperature monitoring feature, and also alarm and LEDS as indicators. The microcontroller programming, sensor integration, circuit design and troubleshooting were the major parts of this project. Upon this project completion, a working prototype which in a form of cooling pad with 3 fans, temperature sensor and indicators is delivered. The prototype working mechanism is based on two threshold temperatures which will control the output of the system. If the input from the temperature sensor exceeds the first threshold temperature, the fans will be switched on to start the cooling mechanism. When the second threshold temperature has been exceeded, the alarms and other indicators will be turned on to warn users of overheating. The deliverables outlined, which are microcontroller programming, and hardware prototyping has been fulfilled. Hence, the requirement of this project which is to deliver a prototype of microcontroller-based external laptop cooling system has been achieved.

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LIST OF ABBREVIATIONS

1. LED – Light emitting diode
2. LCD – Liquid crystal display
3. PIC – Microcontroller, manufactured by Microchip
4. RTD – Resistance temperature detectors
5. IC – Integrated circuit
6. HEX – Code that will be the 'brain' of the PIC. It will be generated after successful compilation of C program and the HEX file will be loaded into the PIC for use.
7. EEPROM – Electrically erasable, programmable, read-only memory
8. WARP 13 – PIC programmer
9. SOIC – System on integrated circuit
10. LSB – Least significant bit
11. RAM – Random access memory
12. I/O – Input/output
13. USB – Universal Serial Bus
14. HS – High speed oscillations
15. OSC – Oscillator
16. ADC – Analog to Digital Converter
17. CPU – Central processing unit
18. GPU – Graphic processing unit
19. PCB – Printed Circuit Board
20. T_{T1} – Threshold temperature 1
21. T_{T2} – Threshold temperature 2

CHAPTER 1
INTRODUCTION

1.1 Background of Study

It is generally known that notebooks or laptops are more compact than desktops. In order to achieve that smaller size, a laptop's internal components - the motherboard, the hard drive, and other components - must be placed in close proximity to one another. The setback is these components produce heat.

Despite internal fans and heat sinks are already included in most laptops; it is more difficult for heat to escape since the interior of laptops are crowded.

The confined heat may affect a laptop's internal components over time. Besides, the bottom of some laptops tends to grow hot after a prolonged period of use. According to BBC News, there has been a case where a Swedish scientist experienced extensive blister after resting his notebook on his lap for about an hour [1].

Nowadays, high-end laptops with prolonged usage time are now fairly popular among developers, students, and serious gamers. However, long uptime means a dire need for effective and reliable cooling system. The incapability to remove excessive heat may lead to permanent damage to the hardware.

Hence, third party laptop coolers must be used to keep laptops cool and to avoid unnecessary damage. From surveys done in computer stores and the Internet, existing low-range and mid-range laptop cooling pad in market only provide basic fans to cool down the laptop; without any other extra features.

1.2 Problem Statement

This project is to design an external cooling system for laptops with additional functionalities such as indicators (LEDs and buzzer) and the ability to control the fan based on the laptop's temperature.

Temperature sensors will be utilized in this project. As the system will be based on microcontroller, programming of Microchip PIC is required.

The designed laptop cooling system must be affordable and with better specifications in order to reach the market successfully.

At the end, the highlight is given to the prototyping of the laptop cooling system. The deliverables of the project are represented in **Figure 1**.

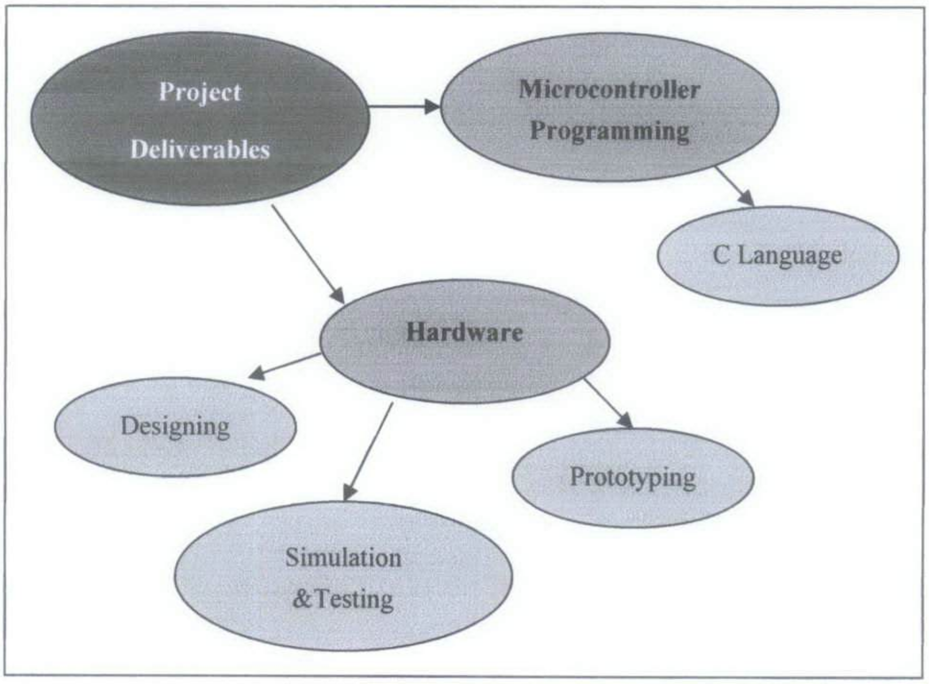

Figure 1 Deliverables of the project

1.3 Objective and Scope of Study

1.3.1 Objective

- Provide an external laptop cooling system with additional functionalities such as indicators (LEDs and buzzer) and the ability to control the fan based on the laptop's temperature
- Enhance the design and performance of the existing product
- Provide a better yet affordable cooling mechanism for user

1.3.2 Scope of study

- Laptop internal cooling system
- Temperature sensor
- Microcontroller
- Electronic circuitry

1.3.3 Feasibility of the Project within the Scope and Time Frame

In general, all scopes covered to complete the project are feasible for a final year student. The allocated time frame of approximately one year is sufficient to carry out the entire task required in the project. **Appendix A & Appendix B** summarized the allocated time frames for all tasks performed throughout the two semesters in a Gantt chart.

CHAPTER 2
LITERATURE REVIEW/ THEORY

2.1 Internal Laptop Cooling System

Laptops are typically made to rest on a solid surface. However, a flat surface is the least desirable angle to dissipate heat. Laptops are not designed to be used on surfaces or in spaces which hinder the free flow of air, since air is one of the important reagents in laptop cooling system.

2.1.1 Conductive and radiative cooling

Some laptop components, such as hard drives and optical drives, are commonly cooled by having them make contact with the computer's frame, increasing the surface area which can radiate and otherwise exchange heat.

2.1.2 Heat sink

A heat sink is an environment or object that absorbs and dissipates heat from another object using thermal contact (either direct or radiant).

Heat sinks function by efficiently transferring thermal energy or heat from an object at high temperature to a second object at a lower temperature with a much greater heat capacity. This rapid transfer of thermal energy quickly brings the first object into thermal equilibrium with the second, lowering the temperature of the first object, fulfilling the heat sink's role as a cooling device.

Efficient function of a heat sink relies on rapid transfer of thermal energy from the first object to the heat sink, and the heat sink to the second object.

The most common design of a heat sink is a metal device with many fins. The high thermal conductivity of the metal combined with its large surface area results in the rapid transfer of thermal energy to the surrounding, cooler, air. This cools the heat sink and whatever it is in direct thermal contact with. In the same way, a fan may improve the transfer of thermal energy from the heat sink to the air [2].

2.1.3 Active heat sink cooling

A fan is directed to blow over or through the heat sink. This results in more air being blown through the heat sink, increasing the rate at which the heat sink can exchange heat with the ambient air. Active heat sinks are the primary method of cooling a modern day processor or graphics card [3].

2.2 Existing Laptop Cooling Pad

There are loads of laptop cooling pads available in the market and they come with various shape and typically run on power drawn through one of the laptop's USB ports. **Figure 2** below shows the common laptop cooling pad with 2 fans. As can be seen in **Figure 3**, cooling pad will be put underneath the laptop and the fans will blow cool air towards the laptop. Cooling pad which is made of heatsink material will have better advantage since it can draw heat from the underside of the computer. The contribution of heat from the energy requirement of the cooler has very minimal impact as most USB ports are limited to 2.5 watts of output power; therefore the cooling effect is dominant.

Figure 2 Common laptop cooling pad

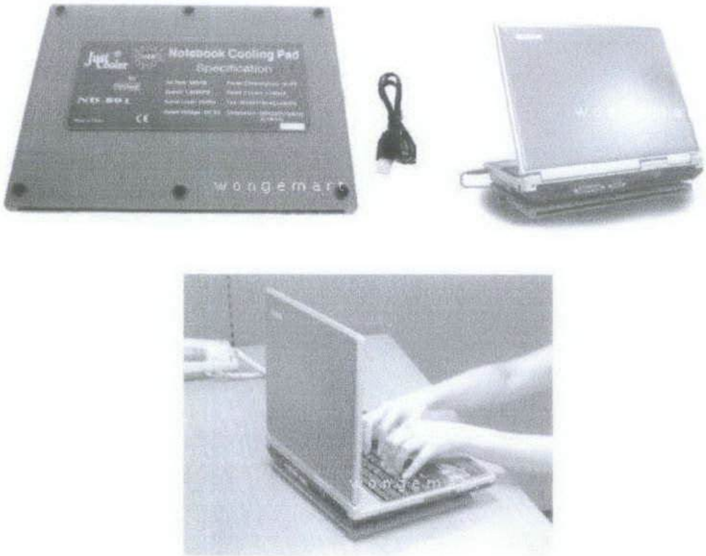

Figure 3 How laptop cooling pad is used

2.3 Temperature Sensor

Temperature sensor can be divided into various families as can be referred in **Table 1**. Each family serves the same purpose which is to detect and measure temperature; hence it is up to user to utilize them based on application requirements.

Table 1 Type of temperature sensors [4]

Family	Output	Accuracy	Integration	Cost
Thermistors	Analog	Good	Easy	Low
Thermocouples	Analog	High	Hard	High
Resistance temperature detectors (RTD)	Analog	High	Hard	High
IR Thermometers	Analog	High	Hard	High
ICs	Digital	High	Easy	Medium
Bimetal	Binary	Low	Very easy	Low
Diodes	Analog	Good	Easy	Very low

2.4 Microcontroller

A microcontroller is a computer-on-a-chip normally used in automatically controlled products and devices. **Figure 4** shows the features embedded in the microcontroller. This integration drastically reduces the number of chips and the amount of wiring and circuit board space that would be needed to produce equivalent systems using separate chips; which made microcontroller highly popular.

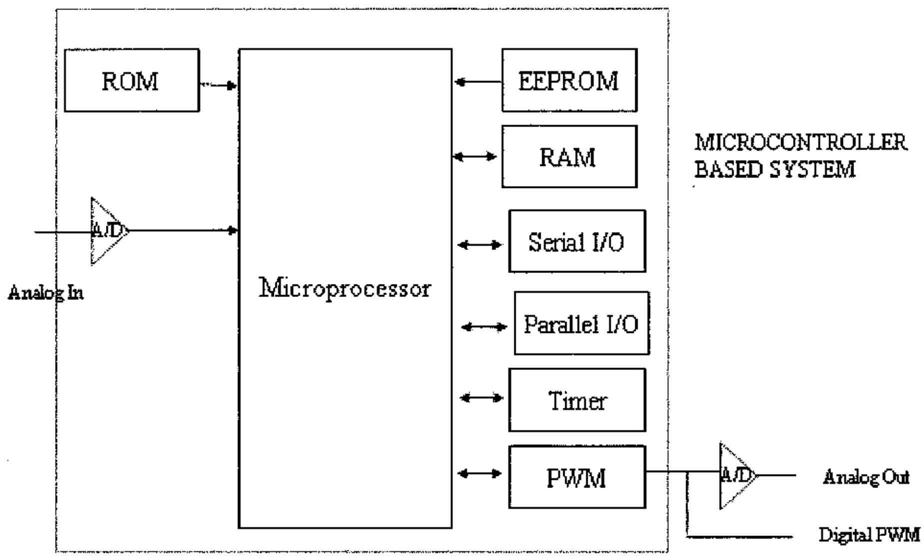

Figure 4 Microcontroller Based System [5]

There are many types of micro-controllers in the market; among them are HC11 and HC12 by Motorola, 8051 by Intel, AVR by Atmel, and PIC / dsPIC by MicroChip [5]. For this project, the selected microcontroller is from MicroChip.

CHAPTER 3
METHODOLOGY/ PROJECT WORK

3.1 Procedure Identification

Figure 5 below outlines the main approaches in accomplishing the project. All procedures were carried out subsequently at all times. If necessary, the previous procedure was revised as to do any modification on the project.

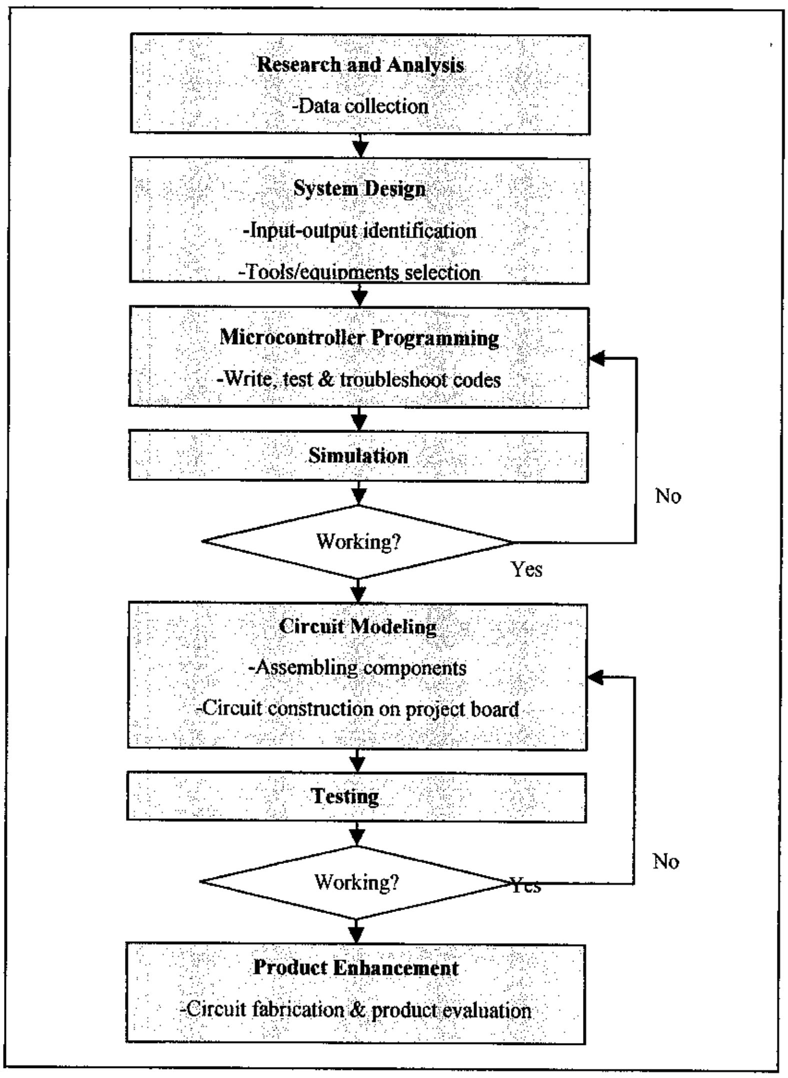

Figure 5 Stages of procedure in delivering the project

3.1.1 Research and Analysis

Research is the prerequisite in the early stage of the project as to pursue on the next procedures of the project. Through the Internet and several references, the preliminary researches were performed on the following matters; laptop cooling system, sensors, and microcontroller. Research and analysis were continuously performed during advancement to the next stages in order to improve the output of this project.

3.1.2 System Design

During this stage, flow of the system and how it will basically work was determined. Tools/equipments selection was carried out. Preliminary input and output components to be integrated on the laptop cooling system circuit were also identified.

3.1.3 Microcontroller programming

The three most common ways that can be used to program the PIC microcontroller are either using the assembly language, PIC Basic or C language. The assembly language and PIC Basic were considered to be quite messy and complicated to be used in programming. Furthermore, it may take more time to understand the deliverables of the built-in functions of assembly language compared to C.

In addition to that, the pseudo code for temperature controller can be easily translated into C language than assembly language. For example, the conditional control operations defined using IF...THEN statements will translate directly, whereas, in assembler, it has to be implemented by suitable combination of 'Bit Test and Skip' with 'Goto' or 'Call'; which is much more complicated.

C language is more straightforward and takes shorter time to be understood. C compiler is made by the third parties to provide practicality to the programmer in coding the PICs. The basic knowledge on C syntax, its built-in functions and pre-processor are essential in pursuing the project to program the microcontroller.

3.1.4 Simulation

Simulation is the process of imitating a real phenomenon with a set of mathematical formulas. In this case, the laptop cooling systems was simulated using C. The simulation stage involved the compilation of the C program, display of the output, and analyzing the execution output. This stage is closely related with the previous stage, which is microcontroller programming stage; as there is always a need to go back and forth for debugging and output improvement.

3.1.5 Circuit Modeling

During this stage, the final input and output components to be integrated on the prototype circuit were determined and then assembled. The examples of project gathered from the Internet gave enormous guidance in the circuit design.

In order to finalize the PIC programming, there should be an assembled circuit to evaluate the feasibility of the program written. Else, the burned program is not giving any use since there is no other viable means to observe the input-output poses of the circuit based on the program written.

The circuit designed was then assembled on the project board for evaluation purpose. Any alterations on the circuit design had been done easily while all the components were being assembled on the board. The microcontroller datasheet was reviewed continuously in ensuring that the input and output components were connected to the correct I/O pins of the microcontroller.

3.1.6 Testing

The product was tested and evaluated after all the components were put on the board to ensure that no fault will occur before soldering process is done. If there is a fault, the troubleshooting will take place.

3.1.7 Product Enhancement

All procedures outlined previously were accomplished and the circuit was fabricated on a Vero board.

3.2 Tools/Components Required

3.2.1 Microchip PIC (16F877)

Microcontroller is the main component in this project. The chosen microcontroller for this project is PIC 16F877 which is manufactured by Microchip.

3.2.2 Temperature sensor

Various temperature sensors in the market had been surveyed and analyzed in order to get the most suitable one for this project. The right type of sensor must be selected in order to ensure the precision of the project output.

3.2.3 PIC C Compiler

PIC C Compiler is the tools used in writing the PIC program using C language. In general, the program written should include the header file of the PIC used, its configuration bits, clock speed which is the value of oscillator used, defining the inputs and outputs used and the main() function. Once the program is completely written, it is compiled to generate the HEX file. If there is an error in the program, the C Compiler stops compiling and at the bottom side of the window, the error identified is highlighted in red.

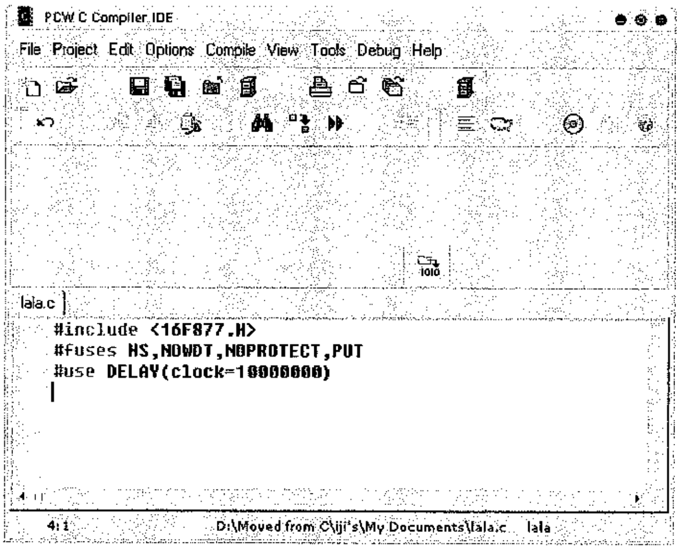

Figure 6 PIC C Compiler program window

3.2.4 PIC Simulator IDE

This powerful tool was used during the simulation stage to simulate the microcontroller mechanism, and can display the simulated output. **Figure** 7 below shows the main application window of PIC Simulator IDE. It shows all PIC microcontroller internal registers status, mnemonics of the last executed instruction, mnemonics of the next instruction that will be executed, clock cycles and instructions counter and real time duration of the simulation [6].

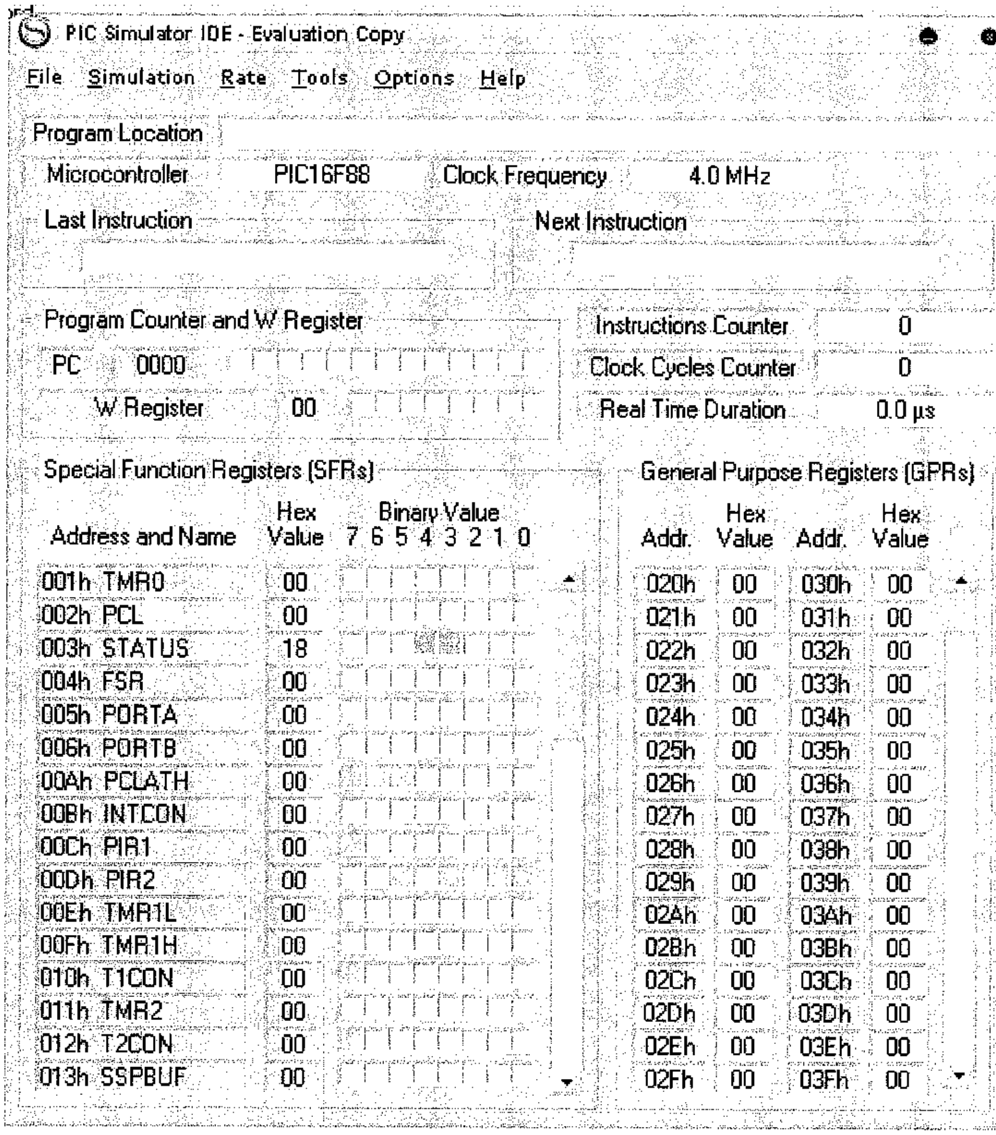

Figure 7 Main application window of PIC Simulator IDE

3.2.5 WARP 13

In succession to the HEX file generation, the HEX code can be burned into the PIC using a chip burner using WARP 13 program. This is the vital part of the microcontroller programming as to ensure its capability to control the circuit system as desired. Before burning any particular program into the PIC, its EEPROM should be erased or blanked. Once the program button is pressed, the program will be written into the PIC memory [7]. **Figure 8** shows the chip burner that will be used for program burning.

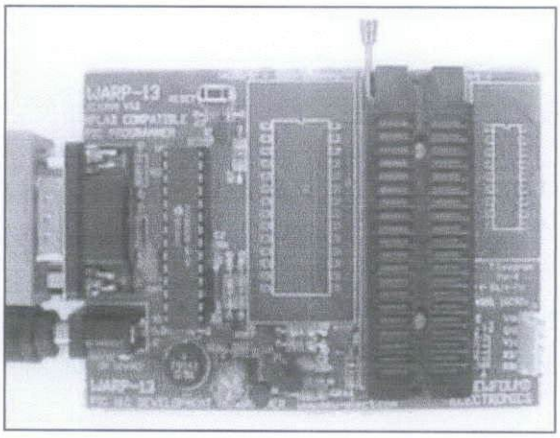

Figure 8 WARP13 PIC programmer

3.2.6 Eagle Version 4.13 for Windows

Easily Applicable Graphical Layout Editor or widely known as EAGLE is a software used for circuit design where the schematic can be drawn and the PCB can be automatically routed from the designed schematic. All the components used in the circuit are available in its library except brushless DC fan.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Research and Analysis

Research on the important components of this project was carried out rigorously. The components were temperature sensor, microcontroller, and threshold temperatures. These components were vital in designing the microcontroller based laptop cooling system.

4.1.1 Temperature sensor

From the analysis of various temperature sensors, the sensor selected for this project was integrated circuit (IC) temperature sensor, LM35DT. Manufactured by National Semiconductor, LM35DT is a precision integrated-circuit temperature sensor suited for low cost and remote applications [8].

LM35DT produces analog output voltage, proportional to the change in surrounding temperature. It can easily be integrated with PIC16F877 as the microcontroller is built with internal analog-to-digital converter (ADC).

Features of this sensor (TO-220 plastic package) are as below:

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts

- Less than 60 µA current drain
- Nonlinearity only ±1⁄4°C typical
- Low impedance output, 0.1 W for 1 mA load
- Temperature rise due to self-heating (thermal resistance, θ_{JA}):
  - Still air: 90°C/W junction to ambient
  - Moving air: 26°C/W junction to ambient

The best feature of this sensor is the output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling.

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Its high accuracy is capable to detect minor changes of temperature; which is very important in order to ensure the effectiveness of the product.

This sensor will generate 0.01 volts (10.0mV) for every degree C, so a temperature of 40 degrees would read 0.40 volts on the meter.

Small size, low cost and ease of use make LM35DT an ideal choice for implementing thermal management in this project.

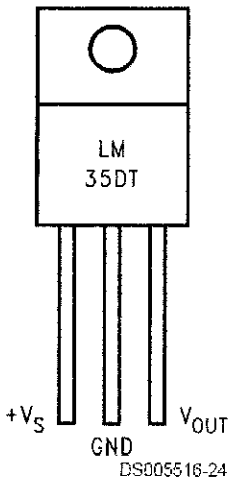

Figure 9 LM35DT Connection Diagram

Table 2   LM35DT Pin Function Table

Name	Function
$+V_S$	Power Supply
V_{OUT}	Output Voltage
GND	Ground

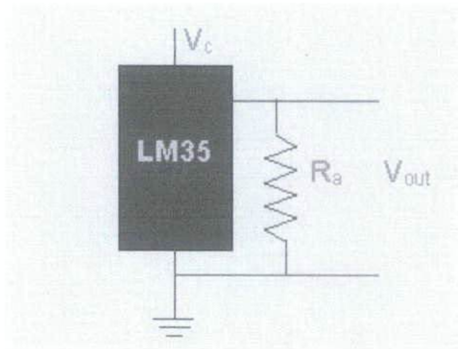

Figure 10   Common LM35 electrical connections [9]

Figure 10 above shows how to use LM35. V_C is the voltage supply which can range from 4 volts to 30 volts. R_a is the resistor that is used to limit the current in the circuit and is calculated using the equation $R_a = V_C / 10^{-6}$.

Another way to connect LM35 to circuit is as in **Figure 11** below:

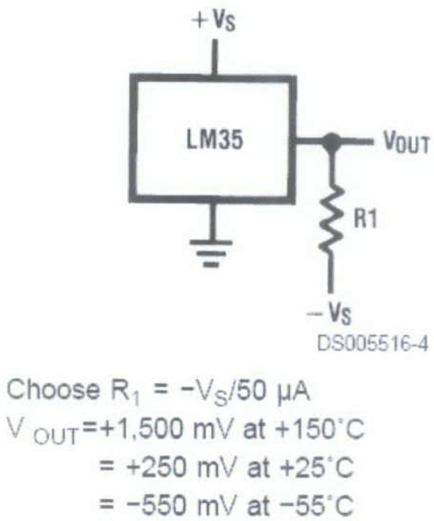

Figure 11   Typical application of LM35DT

4.1.2 Microcontroller

In order to choose the best microcontroller, the nature of the project must be taken into account. This project can be categorized as medium-sized project as it requires medium integration of software and hardware, and also fabrication of the prototype.

Table 3 Comparison of PIC microcontrollers

	PIC16F84	PIC16F877	18F452
Application Range	Small to medium	Medium	Big
RAM space	68 bytes	368 bytes	1536 bytes
Program memory	1 K	8 KB	32 KB
I/O Ports	2 (A & B)	5 (A,B,C,D,E)	5 (A,B,C,D,E)
Reference	Easy	Easy	Hard
AD Converter	No	Yes	Yes

Table 3 above shows comparison of three microcontrollers from the PIC family which are offered by Microchip [5].

The microcontroller that will be used in this project is PIC16F877 for its fair performance and the number of I/O ports available which is 5. PIC16F877 also has a good range of peripheral interfaces and other features, and can be programmed more easily due to easy reference. **Figure 12** below shows the physical exterior of PIC16F877.

Figure 12 PIC16F877

4.1.3 Threshold Temperature

In this project, threshold temperature is the laptop's temperature upper limit that will send the output on. There will be two threshold temperatures, namely T_{T1} and T_{T2}. T_{T1} is the laptop's temperature value that will indicate the need of external cooling. T_{T2} on the other hand is a higher value compared to T_{T1}, which will indicate an unsafe condition of laptop, the hazard of overheating.

In order to establish T_{T2} and T_{T1}, three analysis methods, as below have been taken into account:

- Experiment which measure laptop's temperature by using PASCO DataStudio.
- Survey done by Ubuntu community in their forum site, thread titled "Post your laptop temperature" [14]
- Case study conducted by Nikhil Vichare, Peter Rodgers, Valérie Eveloy, and Michael G. Pecht which titled "In Situ Temperature Measurement of a Notebook Computer—A Case Study in Health and Usage Monitoring of Electronics"

4.1.3.1 Measurement of laptop temperature using PASCO DataStudio

Apparatus used:

1. PASCO Model CI-6526 Type-K Thermocouple Temperature Sensor [10]
2. PASCO 750 USB Interface [11]
3. DataStudio [12]
4. Laptop (COMPAQ Presario 2500)

Figure 13 Type-K Thermocouple Temperature Sensor

Figure 14 USB Interface

Procedure:

1. PASCO Model CI-6526 Type-K Thermocouple Temperature Sensor was connected to analog input of PASCO 750 USB Interface which was connected to the lab computer.
2. The probe of the temperature sensor was attached to the bottom of laptop using tapes.
3. Lab computer was switched on and DataStudio was opened and configured to collect laptop's temperature data over time. The step is as below:
   Create experiment > Sensor > Temperature Sensor > Start
4. Data reading was continued until the laptop's temperature was high enough to shutdown the laptop.
5. Steps above were repeated several times in order to find the mean temperature that will set the laptop off, T_{max}.

Results and Discussion:

Table 4 below shows T_{max} mean calculation:

Table 4 T_{max} mean calculation

	First experiment	Second experiment	Third experiment
T_{max}	78.1°C	75.7°C	74.5°C
Total T_{max}			228.3°C
Mean T_{max} (Total /3)			76.1°C

Conclusion:

The experiment was done in air-conditioned lab and the laptop evaluated was a four-year-old Compaq Presario. 76.1°C is the mean temperature that caused the laptop to automatically shutdown.

4.1.3.2 Ubuntu community survey on laptop temperature[14]

From the thread "Post your laptop temperature", 64 Ubuntu forum members joined this survey. They posted their laptops particular (Model, CPU and GPU type and performance) and temperature during idle, normal and stressed time. The compilation of the survey can be viewed in **Appendix D**. **Table 5** below shows thorough analysis of the survey results.

Table 5 Results analysis of survey on laptop temperature

Temperature range (°C)	Laptop's Condition		
	Idle (Out of 49 response)	Normal (Out of 22 response)	Stressed (Out of 55 response)
20-30	4% (2)	-	-
31-35	4% (2)	-	-
36-40	18% (9)	-	2% (1)
41-45	8% (4)	18% (4)	2% (1)
46-50	30% (15)	13% (3)	-
51-55	12% (6)	22% (5)	5% (3)
56-60	12% (6)	13% (3)	11% (6)
61-65	8% (4)	18% (4)	13% (7)
66-70	2% (1)	4% (1)	24% (13)
71-75	-	-	15% (8)
76-80	-	9% (2)	7% (4)
81-85	-	-	5% (3)
86-90	-	-	7% (4)
91-95	-	-	5% (3)
96-100	-	-	4% (2)
100-105	-	-	-

Conclusion from the survey:

51-55 °C is the range of temperature when laptops are in normal condition (22%).

66-70 °C is the range of temperature when laptops are in stressed condition (24%).

However, ambient temperature must also be taken into account. Most of the survey participants came from America and Europe continent.

4.1.3.3 "In Situ Temperature Measurement of a Notebook Computer—A Case Study in Health and Usage Monitoring of Electronics[15]

From the case study, it is stated that worst-case operating conditions is 68 °C. Besides, laptop's temperature should not exceed processor's maximum base plate temperature which is commonly rated at 75 °C. This is to ensure a product will perform as intended (i.e., without failure and within specified performance limits) for a specified time.

From all three analyses and considering Malaysia's climate, T_{T1}, which indicates the need of external cooling, is set to be 50℃. T_{T2} is set to be 68℃ –indicating an unsafe condition of laptop, the hazard of overheating.

Once the input temperature hits T_{T2}, user will alert of auto shutdown hence have time to save all their works before shutting down the laptop. The complete system flow of laptop cooling system will be explained in next section.

4.2 System Design

4.2.1 System flow

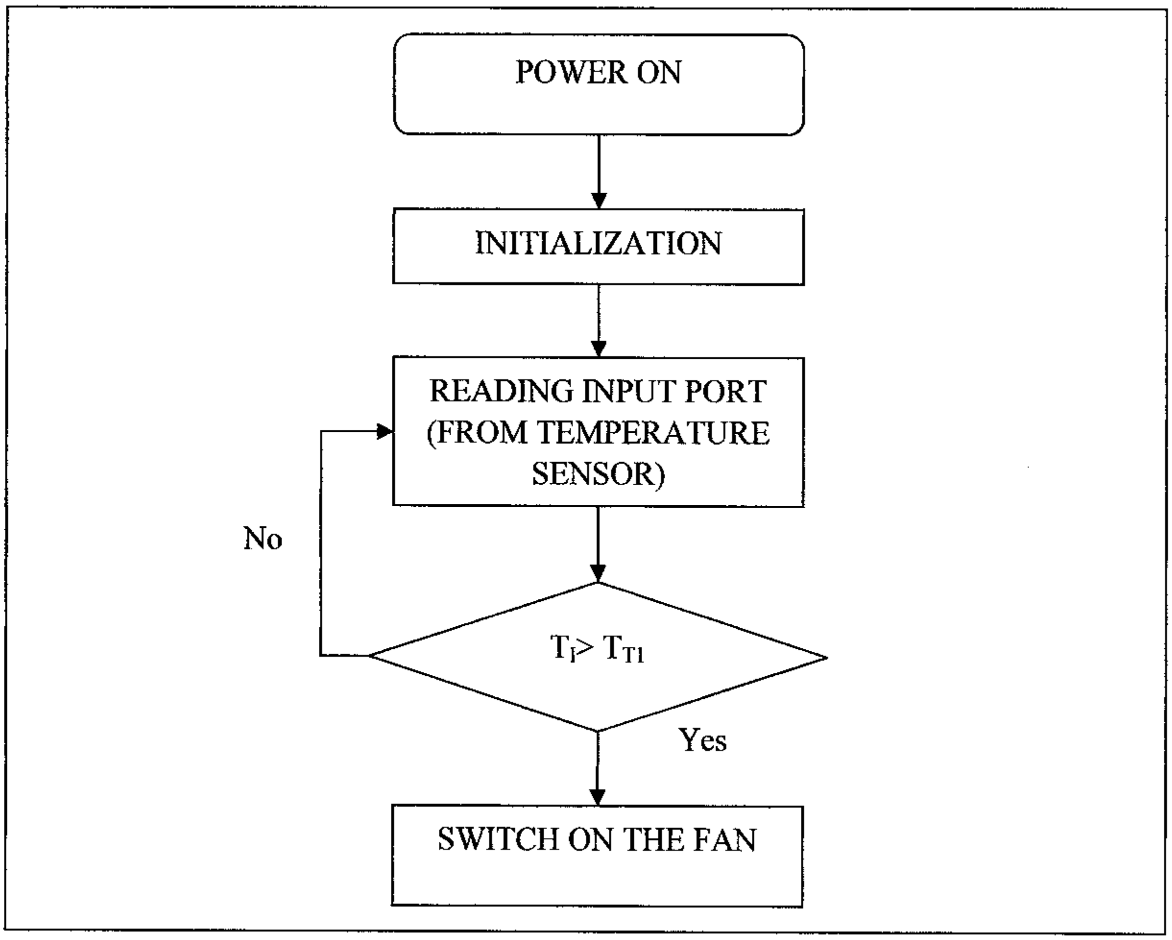

Figure 15 Basic Flow of Laptop Cooling System

In designing a system, a basic flow must be determined first before gradually improving it into a more complex system.

Based on **Figure 15** above, the system will first read the input temperature, T_I then compare the value with the threshold temperature, T_{TI}. If T_I is higher than T_{TI}, the fan will be switched on.

Figure 16 below shows the improved flow of the system.

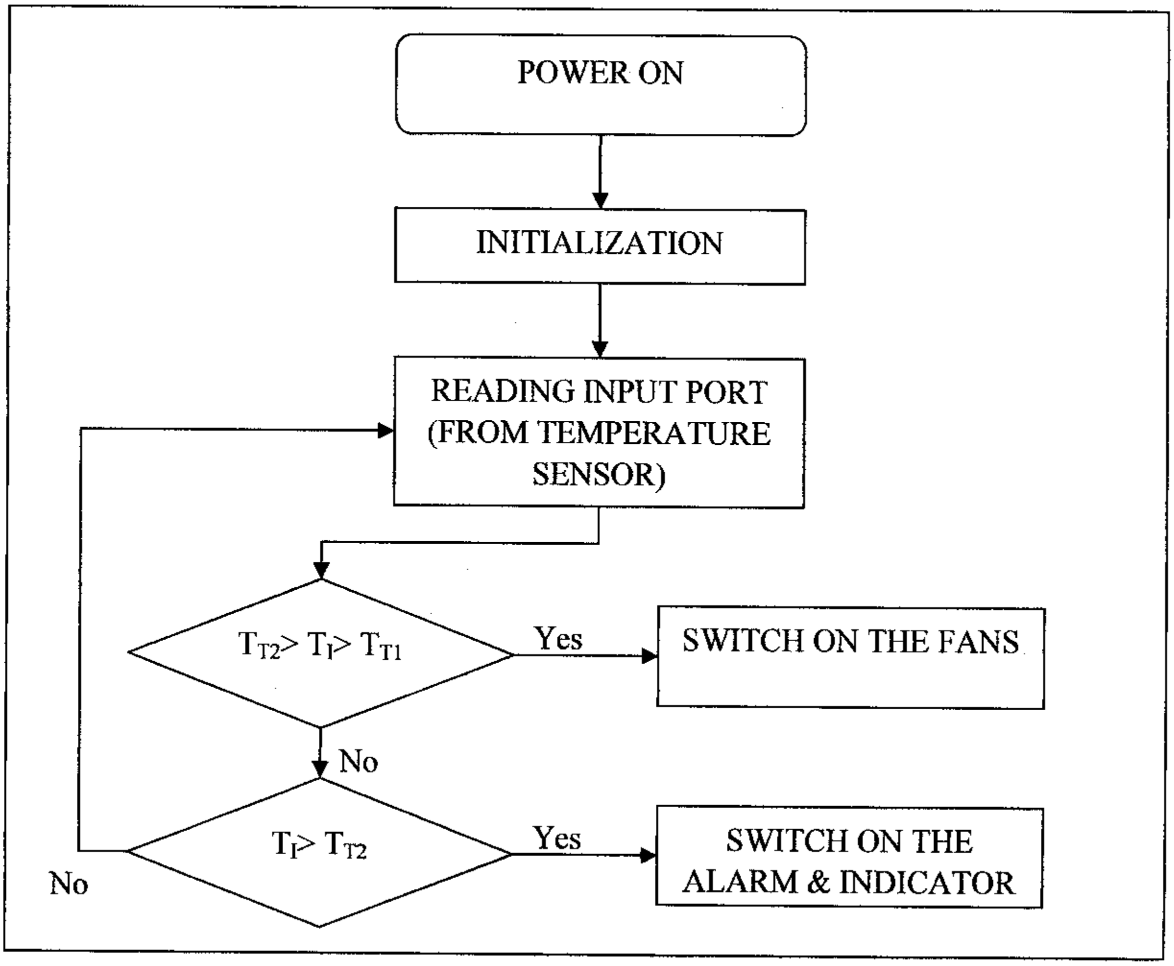

Figure 16 Improved Flow of Laptop Cooling System

For the above figure, there are two threshold temperatures, T_{T1} and T_{T2}. Once the input temperature, T_I exceeds T_{T1} value, the fans will be switched on and if T_I is higher than T_{T2}, the alarm will sound and the indicator (i.e LEDs) will be turned on.

By defining two threshold temperatures, the system will be more effective. By sending alarm during high temperature, users will be aware of overheating and this will alert them to save all their current work in case the laptop will automatically shutdowns.

4.2.2 Prototype Design

Figure 17 below shows the prototype design of the laptop cooling system. The material that will be used as the pad is aluminum, because of its heat sink property. The microcontroller circuit and alarm are put at the bottom of the pad. This prototype consists of three fans and three LEDs as indicator. This cooling pad will be connected to laptop via USB port, which will supply the power to operate the circuit. Temperature sensor is designed to have extended wire so that it can be attached to the bottom of laptop for better accuracy.

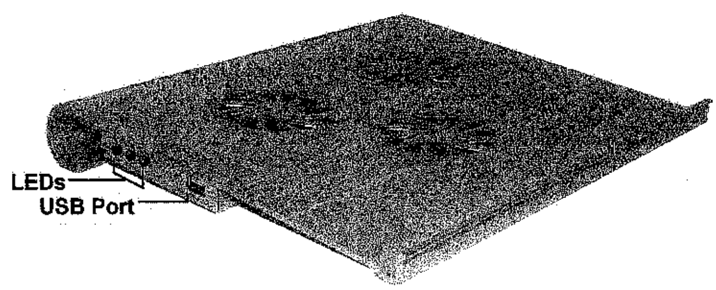

Figure 17 Prototype design

4.3 Microcontroller Programming

For this project, the microcontroller is programmed in C Language. The full coding of the system can be viewed in **Appendix E.**

4.3.1 Header

In C program, header contains some common preprocessor directives; such as #include, #fuses, #use delay (clock speed) [5].

#include tells compiler to include file as part of program. In this project, the file that must be included is register definition header file of PIC16F877.

Code snippet:

```
#include <16F877.h>
```

#fuses is the directive that defines the fuses to be set in device. In setting the fuse, the oscillator circuit that will be used in the hardware must be taken into account.

#use delay(clock_speed) on the other hand tells the compiler the speed of the processor in cycles per second. The clock speed depends on the oscillator used in the oscillator circuit.

The function of an oscillator circuit is to provide an accurate and stable periodic clock signal to a microcontroller. The frequency of this clock signal can range from a few kilohertz to tens of megahertz and determines how quickly the microcontroller executes its instructions [13].

In this project, regular speed oscillation (XT) is used in order to make sure the effectiveness of the system. In establishing XT, an oscillator of 4MHz will be connected to the OSC1 pin of the PIC.

The code snippet that will be used is:

```
#fuses XT,NOWDT,NOPROTECT,NOPUT,NOBROWNOUT,NOLVP
#use DELAY(clock=4000000)
```

4.3.2 Analog to Digital Converter (ADC)

PIC16F877 is built in with 8 channels ADC (pin A0 to A7). The ADC allows conversion of an analog input signal to a corresponding digital number. The PIC also features a 10-bit A/D conversion. However, higher resolution means longer conversion time.

For this project, the writer decided to use an 8-bit A/D module because the voltage change in the input is large enough to be distinguished by the PIC.

8-bit converter will provide outputs from 0 to (2^8-1), 255 to represent the analog input. The conversion of the voltage to digital output can be summarized as:

$$\frac{V_{in}}{V_{fullscale}} = \frac{X}{2^n - 1}$$

X is the digital output and n is the number of bits

Below are the calculations to obtain the voltage-to-temperature conversion formula:

$V_{fullscale} = 5V$

n=8

x=adcValue

Substitute the above values into equation below:

$$\frac{V_{in}}{V_{fullscale}} = \frac{X}{2^n - 1}$$

Since 10mv=1°C, the conversion formula for this project will be:

voltage=5.000*adcValue/255.000

temperature=voltage/0.01

Therefore,

adcValue for T_{T2} will be:

= (68x0.01x255)/5

=34.68

=35 (rounded to decimal)

And

adcValue for T_{T1} will be:

= (50x0.01x255)/5

=25.5

=25 (rounded to decimal)

For this project, the codes to be added in the C program are as below:

```
#device ADC=8

unsigned int8 adcValue;

setup_adc_ports(ALL_ANALOG);   //setup all Port A for analog input
setup_adc(ADC_CLOCK_INTERNAL);

set_adc_channel(1);            //prepare to read analog input from channel 1
delay_us(30);

adcValue=read_adc();
```

4.3.3 Looping and Conditional Statements

Below is the C code of feedback operation of the cooling system. In this coding, *while* loop and *if else* statement are employed.

```
while(1)
{
if(adcValue>25 )                    // adcValue for TT2 is 25
        output_high(pin_B1);        //relay 1 on – first fan on
        output_high(pin_B2);        //relay 2 on – second fan on
        output_high(pin_B3);        //relay 3 on –third fan on
        output_low(pin_C1);         //LED1 off
        output_low(pin_C2);         //LED2 off
        output_low(pin_C3);         //LED3 off
        output_low(pin_B4);         //buzzer off

else if (adcValue>35)               // adcValue for TT2 is 35
        output_high(pin_B1);
        output_high(pin_B2);
        output_high(pin_B3);
        output_high(pin_C1);        //LED1 on
        output_high(pin_C2);        //LED2 on
        output_high(pin_C3);        //LED3 on
        output_high(pin_B4);        //buzzer on

else if(adcValue<25 )
        output_low(pin_B1);         // first fan off
        output_low(pin_B2);         //second fan off
        output_low(pin_B3);         // third fan off
        output_low(pin_C1);         //LED1 off
        output_low(pin_C2);         //LED2 off
        output_low(pin_C3);         //LED3 off
        output_low(pin_B4);         //buzzer off
}
```

4.4 Circuit Modeling

The schematic shown in **Figure 18** below represents the circuit design of microcontroller based laptop cooling system.

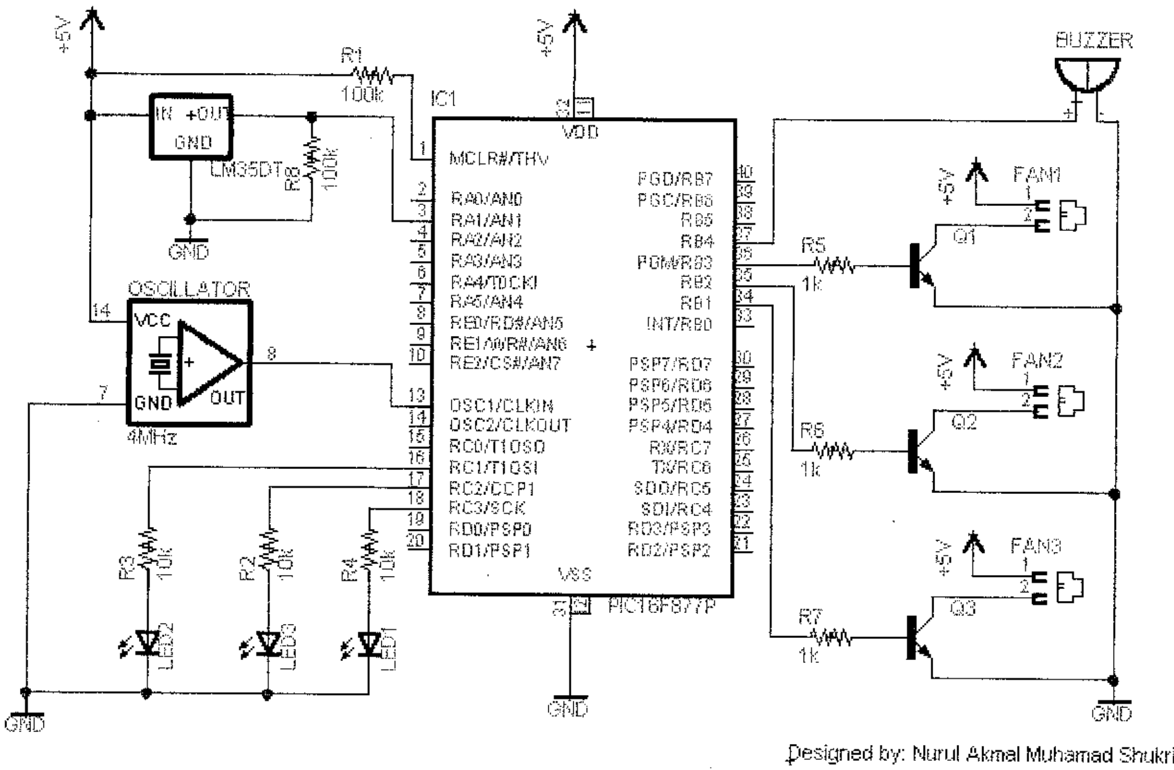

Figure 18 Circuit design

4.4.1 PIC Oscillation Circuit

The function of an oscillator circuit is to provide an accurate and stable periodic clock signal to a microcontroller (as explained in **Section 4.31**). Oscillator is connected to Pin 13 (OSC13) of PIC16F877. VCC pin of oscillator is connected to 5V power supply while GND pin is grounded. (Refer **Figure 19** below)

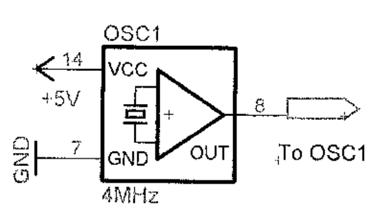

Figure 19 Diagram of PIC oscillation circuit

4.4.2 Temperature Sensor Circuit

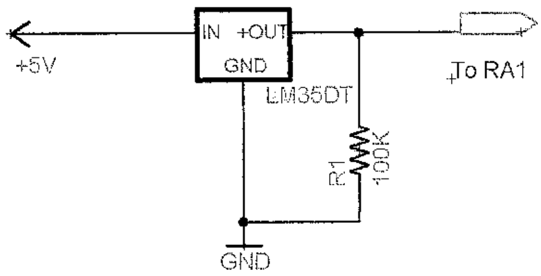

Figure 20 Diagram of temperature sensor circuit

Based on **Figure 20** above, the temperature sensor, LM35DT is connected to Pin 3 (RA1) of PIC16F877, which is in Port A. Port A of PIC16F877 has 8 input channels of 10 bit analog-to-digital module. Pin RA1 which is also known as AN1, accept analog input from the sensor and then converts it into digital output. A resistor (100KΩ) is added between the analog signal and GND for stability [17].

4.4.3 LED Circuit

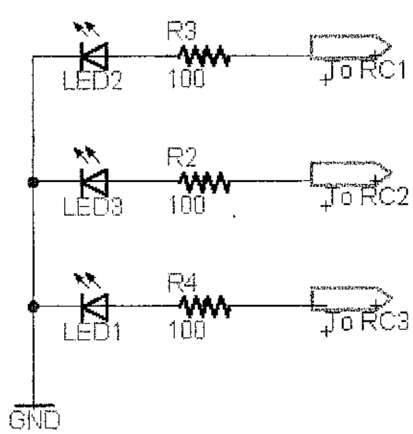

Figure 21 Diagram of LED circuit

One I/O pin is needed for one LED as output for PIC16F877. The connection for LEDs to I/O pins is shown in **Figure 21** above. The LEDs are connected to Port C of microcontroller – LED1 to Pin 18 (RC3), LED2 to Pin 17 (RC2) and LED3 to Pin 16 (RC1). The function of resistor R2, R3, R4 is to protect the LEDs from over current that will burn the LEDs.

4.4.4 Buzzer Circuit

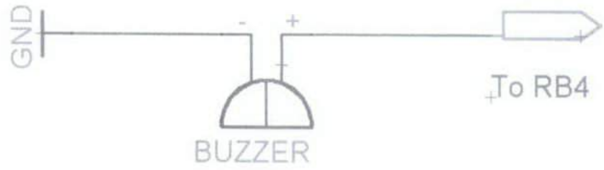

Figure 22 Diagram of buzzer circuit

As shown in **Figure 22** above, the piezo buzzer is connected directly to Pin 37 (RB4) of PIC.

4.4.5 Fans Circuit

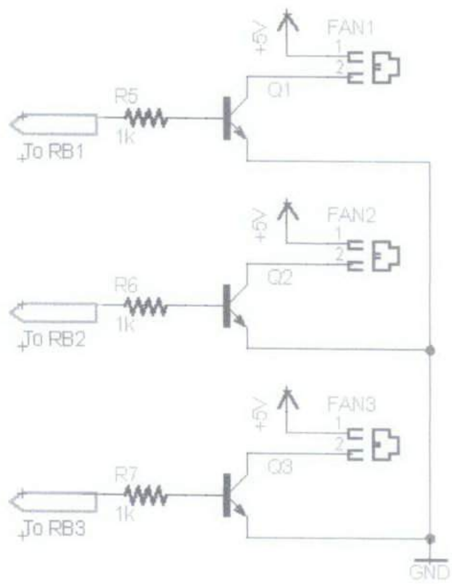

Figure 23 Diagram of fans circuit

One I/O pin is needed for one fan as output, as shown in **Figure 23** above. The fans (5V DC brushless fan) are connected to Port B of microcontroller – FAN1 to Pin 36 (RB3), FAN2 to Pin 35 (RB2) and FAN3 to Pin 34 (RB1).

Maximum current that can be sunk from each I/O pin of PIC is 25mA, which is extremely limited. Since the current needed to drive each fan is 0.12A, so power transistor (BD135) is required for supplying current sufficiently. The maximum collector current, Ic of BD135 is 1.5A, which means the DC brushless fan greater than 1.5A cannot be driven [17].

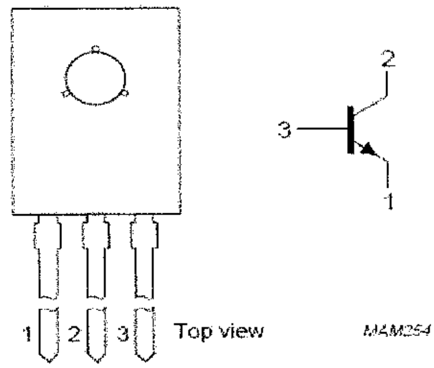

Figure 24 Pin diagram of BD135

Table 6 Pin description of BD135

Pin	Description
1	Emitter
2	Collector
3	Base

Figure 24 above shows the pin diagram of BD135 and **Table 6** describes each pin function. Pin 3 (base) of the transistor is connected to I/O pin of PIC16F878. Pin 2 (collector) is connected to the brushless fan, in order to supply ample current for the fan to work. Pin 1 (emitter) is grounded.

4.4.6 Power Supply Circuit & Reset Circuit

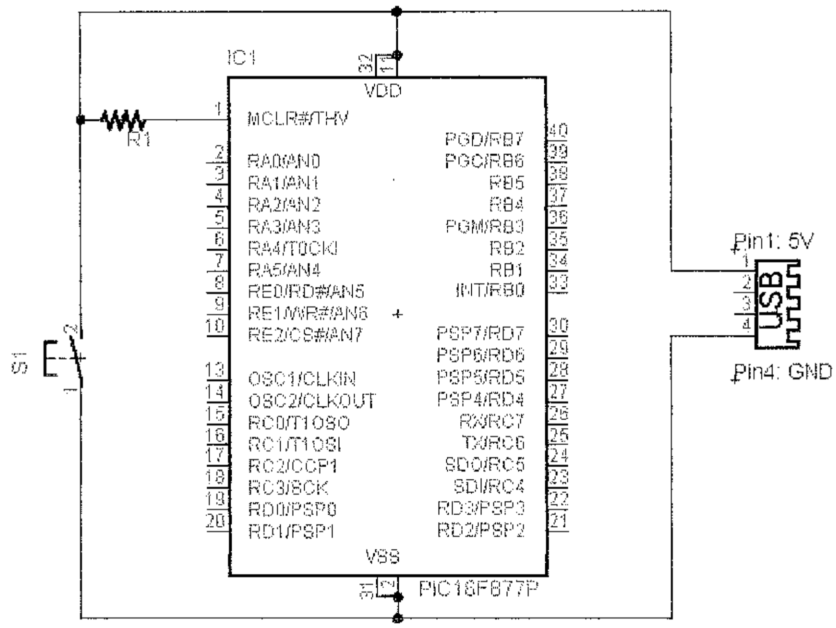

Figure 25 Diagram of power supply circuit and reset circuit

The whole system circuit gets +5V power supply from the computer USB port. The circuit in **Figure 25** above shows PIC power pins (Pin 11, Pin 32) and ground pins (Pin 12, Pin 31) connected to the supply from USB port.

Table 7 Pin description of USB connector [19]

Pin	Name	Cable colour	Description
1	VCC	Red	+5V
2	D-	White	Data out
3	D+	Green	Data in
4	GND	Black	Ground

Table 7 above describes each pin of USB connector. As can be seen in **Figure 25**, only Pin 1 and Pin 4 of USB are used. This is because no data transfer involved between the PIC16F877 and USB. Only power is drawn from the USB port.

For the reset circuit, Pin 1 (MCLR) of microcontroller is connected to the USB power supply as well. This pin is an active low pin, so it is connected to Pin 1 (VCC) of USB. To reset the device (input or programming voltage input), a toggle switch is put in between the MCLR pin of microcontroller and GND pin of USB. Once the switch is pushed, the microcontroller is reset.

While resetting, voltage spikes from VSS at the MCLR pin, induces currents greater than 80 mA, and it may cause latch-up. Latch up is a phenomenon of unintended creation of a low-impedance path between the power supply rails of an electronic component, triggering a parasitic structure, which then acts as a short circuit, disrupting proper functioning of the part and possibly even leading to its destruction due to overcurrent [20].

Thus, a resistor of 10KΩ is put in series to the MCLR pin, rather than pulling this pin directly to VSS [16].

Table 8 Summary of I/O pins assignments of PIC16F877

Pin	Assigned for
RA0	Temperature sensor input
RB1	Output to fan
RB2	Output to fan
RB3	Output to fan
RB4	Output to buzzer
RC1	Output to LED
RC2	Output to LED
RC3	Output to LED

Table 8 above concludes the I/O pins assignments of PIC16F877 for this microcontroller-based laptop cooling system.

4.5 Product Enhancement & Evaluation

The final enhancement stage emphasizes on circuit fabrication and product evaluation. Later, the fabricated circuit is put underneath the aluminium pad. Once accomplished, the final product is evaluated.

4.5.1 Circuit fabrication on Vero board

While performing the soldering task, PIC16F877 should not be overheated due to its heat sensitive property. Else, it might be damaged. As an early precaution, the microcontroller is not going to be soldered directly onto the board. Instead, the IC socket as shown in **Figure 26** is going to be used. Later, the IC can be plugged in. This also provides an added advantage since it can be easily removed for further modifications of the PIC program.

Figure 26 IC sockets

4.5.2 Prototype testing using alcohol lamp

The product evaluation is performed by connecting the final prototype to any USB port for power supply and then utilizing alcohol lamp for heat source. Alcohol lamp is great for lab experiments or for heating something for a science project because it provides good heat supply with small, hot, and consistent flame [21].

For this project testing, alcohol lamp is firstly heated until desired temperature has been reached. Next, the laptop cooling pad will be put on the stand (as in **Figure 28**) for a while until the heat radiates enough to switch the outputs on.

Figure 27 Common alcohol lamp used in laboratory

Figure 28 Alcohol lamp stand

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The allocated project tasks for the whole two semesters had been performed completely. The outlined study scopes have been covered thoroughly. The provided time frame was proven to be adequate for the project accomplishment.

The deliverables outlined, which are microcontroller programming, and hardware prototyping has been fulfilled. Hence, the requirement of this project which is to deliver a prototype of microcontroller-based external laptop cooling system has been achieved.

5.2 Relevancy to the Objectives

The knowledge of basic electronics learned during the early years of study was reapplied in designing the circuit. In addition, new experience had been gained in using microcontroller as the mean of controlling in designing the system.

The skills in C programming are augmented through the C language written to program the PIC. The understanding of the C syntax and its built-in functions had been enhanced through the analysis on program examples. In the beginning of the programming stage, the heuristic approach was applied in getting the desired output behavior from the circuit.

Proper testing method has been learned and applied as well throughout the completion of this project.

5.3 Recommendations

There are certain recommendations that need to be highlighted. They are discussed herein below:

- The system can be enhanced by replacing normal fans with speed-controllable fans. When threshold temperature 2 (T_{T2}) has been reached, the speed of the fans will increase to give more cooling power. Hence, instead of saving all works and preparing to shutdown the laptop, users can get extra peace of mind by sitting back and letting the cooler do the cooling works.
- In future, LCD can be added so that user can easily see the current laptop's temperature.
- The circuit should be fabricated on a PCB board instead of being soldered on the Vero board. This approach can reduce the size of the circuit aside from making the circuit neater.
- Extra indicator can be inserted into the system to warn user when any fan is not functioning.
- The warning system can be improved by sending alerts directly to the laptop, for example, a warning message of overheating will pop up in windows. This way, user will be fully conscious of the laptop's condition. It gives advantage in term of efficiency although the cost and complexity of the whole system may increase.
- When T_{T2} has been reached and user is not around, the system will trigger automatic shutting down of laptop.

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APPENDIX A: GANTT CHART OF FYPI

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SW	EW
1	Selection of Project Topic																
	✓ Topic Approval																
2	Preliminary Research Work																
	Learning Stage																
	✓ Familiarization with microcontroller																
	✓ Make initial design																
	✓ Literature Reviews																
3	Submission of Preliminary Report																
4	Project Work																
	Data Gathering																
	✓ Familiarization with designed system																
	Developing and improving the design																
	Programming the controller																
	✓ Testing																
5	Submission of Progress Report																
6	Project Work Continue																
	✓ Analysis and Troubleshooting																
7	Submission of Interim Report																
8	Oral Presentation																

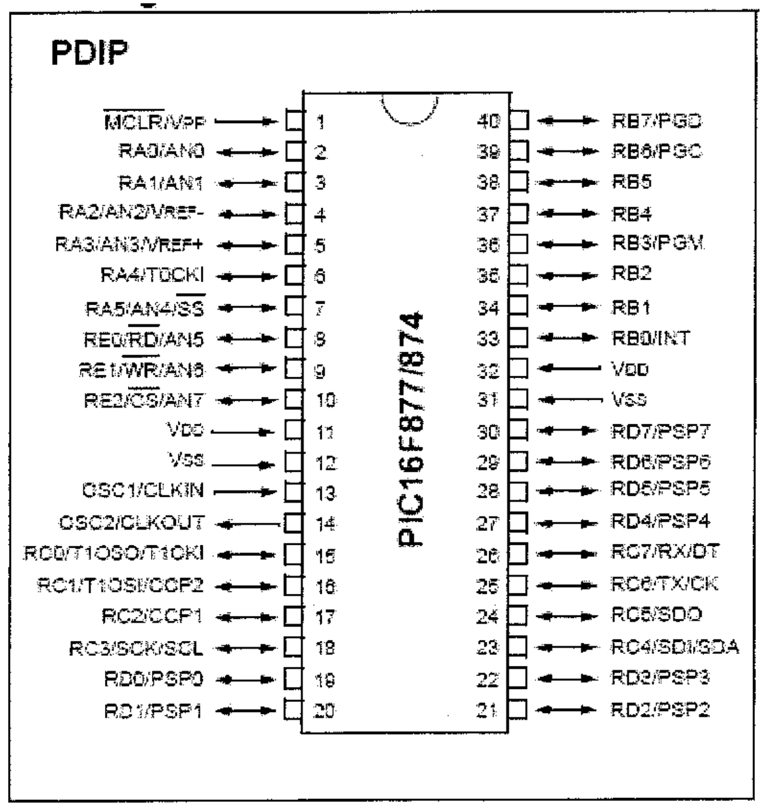
APPENDIX B: GANTT CHART OF FYPII

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue														
	-Microcontroller programming														
	-Assembling components														
2	Submission of Progress Report 1			●											
3	Project Work Continue														
	-Microcontroller programming														
	-Simulation														
4	Submission of Progress Report 2								●						
5	Project work continue														
	-Circuit modelling & testing														
	-Product enhancement														
6	Submission of Dissertation Final Draft												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation														●

● Suggested milestone
Process

Process

APPENDIX C: DIAGRAM OF PIC16F877



APPENDIX D: LAPTOP TEMPERATURE SURVEY COMPILATION

Laptop's Particulars			Laptop's Temperature (°C)			Room Temperature (°C)
Brand	CPU	GC	Idle	Normal	Stressed	
HP Pavilion ZV5474EA	AMD64 3400 (2.2Ghz)	NVIDIA GeForce4 440 Go	50	-	60-70	27-30
AOpen 1557gls	Intel Pentium M (1.8Ghz)	ATI Mobility Radeon 9700 (128M)	50	-	60-90	25-32
Inspiron E1405	CoreDuo T2300E	Intel GMA 950	30	-	47-51	26
Acer TravelMate 654LC	Pentium4m 2.2.GHz (1.18 GHz)	ATI 7500 mobile 32MB	54	-	71	-

Centrino Acer TravelMate 4000	-	-	-	-	96.5	-
HP nx6110	Celeron-M 360J (1.4 GHz)	Intel GMA 915	49	-	57-68	27
Dell Latitude C600	Pentium III 850MHz	-	50-60	-	85	26
Dell Inspiron 6000	Centrino 1.6 GHz	Intel i915	35-40	-	55-65	-
Fujitsu Siemens Amilo Pro 2040	Centrino-M 1.6 GHz	Intel 915	49-50	-	60-62	24-30
ThinkPad T43	-	-	41	-	48-51	25-30
Sony Vaio FS740W	Centrino 1.7GHz	Intel 915	38	43	50-60	15-20
Dell XPS Gen2	Pentium M 2.13 GHz	nVIDIA 6600 GO	-	47	-	27

Pavilion ze5702ea	Intel(R) Celeron(R) CPU 2.80GHz	-	37	49	55-60	27
Dell Latitude C610	-	-	45-55	-	55-70	-
Fujitsu-Siemens Amilo A	CPU 1.6 GHz	-	50-60	-	84	-
Dell Inspiron 8200	Pentium 4-M 1.7 Ghz	GeForce 2 Go	47-52	-	53-60	-
Mitac 8355	Mobile Athlon 64 3000+	-	40	53	60-70	15-20
Sony Vaio VGN A230p	Centrino 1.6GHz	ATI Radeon 9200	-	52	-	-
Gateway 200x	Centrino 1.4GHz	-	43-45	-	65-70	-
Gateway	1.17Ghz	-	-	57	-	-

-	Pentium M 1.7ghz	-	48	-	60-70	-
IBM Thinkpad T23	Pentium III Mobile 1.13 Ghz	-	45	-	74	-
-	Core Duo T2250	-	-	44	-	-
Asus M6Ne	Pentium M 1.6Gh	ATI 9700 mobile 64MB	64	-	94	30
Dell Latitude	-	-	21-30	-	44	-
Dell Latitude D630	Core Duo 2.0 Ghz	nVidia Quadro NVS 135M	47-50	55-60	67-70	27-32
Toshiba Satellite 2410	-	-	-	55	-	-
Asus W2JC	T2500 (2GHz)	TI Mobility X1600 (256 Mo viedo memory)	-	51	69-70	26

-	Pentium M	-	-	-	70-74	-
IBM Thinkpad T40	-	-	-	44	-	-
Acer Aspire 1694wlmi	-	-	-	-	60-80	-
Acer aspire 1522WLMi	AMD64 3000 (1.8Ghz)	NVIDIA GeForce FX Go 5700	50	-	60-85	20-28
Toshiba-satellite m35	-	-	-	60-65	70-75	-
Dell M65 (T2500)	-	-	35-41	58-61	65-67	32
Alienware MJ-12m 5500	Pentium IV 3.4 Ghz	-	32	-	40	22-24
HP Pavilion DV1000	Centrino 1.6 GHz	-	58	80	70-95	-
-	-	-	53	60	75	-

HP Pavilion ze5185	Pentium IV 2.4 GHz	ATI Radeon Mobility M6 LY (32 Mb)	59-62	-	68-72	-
Toshiba 2410-303	Pentium 4 M 1.7 GHz	NVIDIA GeForce4 420 Go	50	-	55	27
Samsung X05	Centrino based 1.4 GHz Pentium M	-	38 - 40	-	60 - 65	-
Compaq V2000Z	Sempron 3300+ 2.0GHz	-	45-50	-	55-65	-
HP Pavilian ZE1000	Mobile Athlon XP +1800	-	60-65	-	80-90	-
Fujitsu-Siemens Amilo Si 1520	Centrino Duo T2300 (2x1.6 GHz)	-	-	45-50	50-60	-
Asus A6Va	Centrino 1.86Ghz	Ati X700 128	40 -50	55-65	79	-

Dell E1505	-	-	35-40	-	60-65	-
Acer Aspire 5002WLMI	-	-	45-50	-	50-60	-
Toshiba Tecra S2	Intel Pentium M 2.0 Ghz	GeForce Go 6600	33	-	-	-
ACER FERRARI 1000	-	-	35-40	-	55-60	-
Compaq M2010	Celeron M 1.3 ghz	-	50-55	-	65-70	-
-	-	-	69	78	90	-
Toshiba Satellite Multi Media	Intel Centrino 3.2ghz	-	-	44	-	-
Acer Aspire 5101	Amd Turion 64	-	37	51	-	-
Philips X56	Core 2 Duo T5600	-	49	-	75	-

Thinkpad R40	P4M 2.0 Ghz	-	54-57	-	65	-
Compaq Presario 1500US	Pentium IV (2.4Ghz)	ATI Mobility Radeon 7500 - 32MB	56	-	60-77	23
Toshiba Satellite A-65-S126	2.8Ghz Celeron	-	45-50	60-70	80	-
Acer TravelMate 4101	CPU Pentium M 1.6GHz	-	50-60	-	65-70	-
Dell Latitude D630	Core Duo 2.0 Ghz	nVidia Quadro NVS 135M	46-54	-	60-65	30-32
Toshiba Satellite P100	-	-	-	45-65	70-90	-
Dell 640m (e1405)	Core 2 Duo @ 1.83ghz	-	42-48	-	60-68	25-30
ASUS A6VA	Pentium M 1.73Mhz	ATI X700	60-65	-	85-95	-

Dothan 1,86 - X700	-	-	-	-	80-100	
IBM Thinkpad T30	Pentium 4 M 1.8GHz	-	42-47	-	70-75	-
Dell Vostro 1500	Intel Core2Duo T7500 (2.2Ghz)	NVIDIA GeForce 8600M GT	42	-	60-70	21

APPENDIX E: FULL CODING OF THE SYSTEM

```
#include <16F877.h>
#device ADC=8
#include <string.h>
#fuses XT,NOWDT,NOPROTECT,NOPUT,NOBROWNOUT,NOLVP
#use DELAY(clock=4000000)

unsigned int8 adcValue;


void main()
{
setup_adc_ports(ALL_ANALOG);   //setup all Port A for analog input
setup_adc(ADC_CLOCK_INTERNAL);

set_adc_channel(1);                //prepare to read analog input from channel 1

output_low(pin_B1);
```

```
output_low(pin_B2);
output_low(pin_B3);
output_low(pin_C1);
output_low(pin_C2);
output_low(pin_C3);
output_low(pin_B4);

while(1){

delay_us(10);
adcValue=read_adc();

if(adcValue>35)                    // TT2
{
output_high(pin_B1);
output_high(pin_B2);
output_high(pin_B3);
output_high(pin_C1);        //LED1 on
output_high(pin_C2);        //LED2 on
output_high(pin_C3);        //LED3 on
```

```
output_high(pin_B4);          //buzzer on
}
else if(adcValue>=25&&adcValue<=35)       //TT1
{
output_high(pin_B1);
output_high(pin_B2);
output_high(pin_B3);
output_low(pin_C1);
output_low(pin_C2);
output_low(pin_C3);
output_low(pin_B4);
}
else
{
output_low(pin_B1);
output_low(pin_B2);
output_low(pin_B3);
output_low(pin_C1);
output_low(pin_C2);
output_low(pin_C3);
```

APPENDIX F: BILL OF MATERIALS

No	Component	Quantity
1	PIC16F877 microcontroller	1
2	LM35DT temperature sensor	1
3	Aluminium pad	1
4	5V DC brushless fan	3
5	Red light emitting diode (LED)	3
6	Piezo buzzer	1
7	10MHz oscillator	1
8	100nF capacitor	1
9	0.1μF capacitor	1
10	100Ω resistor	3
11	10kΩ resistor	1
12	BD135 power transistor	3
13	USB cable	1
14	40-pin IC socket	1
15	Vero board	1